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# Maine Agricultural Experiment Station

ORONO

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## THE INFLUENCE OF ULTRA-VIOLET LIGHT ON NUTRITION IN POULTRY.

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## BULLETIN 320

# THE INFLUENCE OF ULTRA-VIOLET LIGHT ON NUTRITION IN POULTRY.

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### INTRODUCTION

The incidence of a condition of weakness in the legs among young chicks has long been recognized by poultrymen as one of their problems. The present bulletin aims to discuss some phases of this disease, and to present the effect, upon its incidence and course, of exposure of the chicks to the ultra-violet rays generated by a quartz mercury vapor arc lamp.

It is not for a moment claimed that the problem is a new one, or that the work herein described is the last word on the subject. Rather it is hoped that the report of the experiments here enumerated will aid in our understanding of the preventive and curative measures which are best suited to combating this disease.<sup>1</sup>

The disease has been described by Salmon<sup>2</sup> as follows: "The chick is not vigorous at the age of three weeks, and at four weeks begins to show signs of an inability to walk. This condition becomes more and more noticeable until the chick is totally unable to stand, and is obliged to use its wings for support when moving after food. If allowed to reach this stage, the chick soon dies."

By practical experience and observation, breeders of poultry have found that light and air are in some definite way influential in preventing or curing this disease. This has led to the

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<sup>1</sup>The use of the term "disease" is made with reservation that it is intended to signify a condition of physiological and chemical unbalance due to deficient diet.

<sup>2</sup>Salmon, D. E., "Important Poultry Diseases," U. S. Dept. of Agric. Farmers' Bulletin No. 530, pp. 1-36, 1913.

belief that it is caused by improper housing and feeding conditions. Salmon lists the following: uneven distribution of heat in the brooder, damp and poorly ventilated houses, small pens having dry board floors. He recommends as treatment the feeding of a diet of bran, barley, green food, skim milk, and vegetables—at the same time allowing the chicks to run in a yard to get plenty of fresh air and sunlight.



FIG. 16. General appearance of treated (right) and control (left) chicks at age of 5 weeks. X-ray photos of these chicks are given in Figs. 19 and 20.

As shown by the photograph above (figure 16), weakness in the legs of chickens is the expression of improper formation of the bones. The experiments show that an essential cause of this disease is the lack of proper exposure to sunlight. The **uneven** distribution of heat in the brooder, the damp and poorly ventilated houses, or the small pens with dry board floors, we believe to be relatively insignificant factors as compared with the proper exposure to sunlight.

To calculate the importance of light as an essential factor in the growth of chicks is not always easy. One could not be expected to discover its importance unless one should carry out carefully planned experiments such as are described in this bul-

letin. We make this statement with conviction of its truth, because the beneficial effects of light are due to a kind of light which comes from the sun, but *which does not pass through the glass windows of the chicken house*. This kind of light can only enter the hen-house through an open door or window, and it is therefore easy to be entirely unaware of its existence. If we compare the growth of chicks in the hen-house with the windows closed, with their growth in the hen-house with the windows open, we observe that the open windows provide the chicks with a greater amount of fresh air, and we should ordinarily ascribe any beneficial effects to the more efficient ventilation. If, however, we know of this type of light, shut out by ordinary glass, there becomes available another factor to be reckoned with.<sup>3</sup>

In all this work, it will be well from the outset to recognize the fact that we are dealing with a disease of a particular type. It is characterized by a deficiency—a falling below normalcy in one or more dietary or physiological elements. What we must do as preventive or curative measures is, therefore, to build back by adding the lacking elements or a substitute until normalcy is again obtained. If conditions are exceptional, we may find, as we did in the comparison between chicks raised out of doors on the ground in the sunlight, and those raised in a greenhouse under the ultra-violet rays, that the latter grew faster and made in general the better record.

All necessary elements except those in which the animal is deficient must be present abundantly or the mere fact that the deficient element or its substitute is added will not produce the desired result.

The ray in sunlight which is essential to the normal formation of the bones of chickens is, as above stated, invisible to our eyes, that is, it is not perceived by us as visible light. This fact is brought out with remarkable clearness in the experiments described below. Weakness of legs occurred in chicks which were raised in a well-lighted and well-ventilated greenhouse but received their only sunlight through a glass roof.

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<sup>3</sup>Based upon extensive investigations conducted by this Station, the open-front poultry house was developed. The practical value of this type of house is now recognized by large numbers of successful poultrymen. This house is described in Poultry Management at the Maine Station, Circular 515.

## THE KIND OF LIGHT WHICH PREVENTS LEG WEAKNESS IN CHICKENS

When sunlight is reflected from rain drops or when it is passed through a wedge of glass, (glass prism), it is separated into seven colors, the colors of the rainbow. These colors always appear in this order: violet, indigo, blue, green, yellow, orange, red and this is also the order in which they appear in a beam of sunlight which has passed through a glass prism. This array of colors is called the "spectrum" of the sunlight, and since the colors are visible, the more specific name "visible spectrum" is often used. The colors in order from one end of the scale to the other are as follows:

<i>Ultra-Violet</i> (invisible)	
Violet	} (visible)
Indigo	
Blue	
Green	
Yellow	
Orange	
Red	
<i>Infra-red</i> (heat) (invisible)	

We recognize these as "colors" in the sunlight because they produce the sensation in our eyes. However, these seven colors do not include all that comes from the sun, for it is possible to show by suitable instruments that below the red in the spectrum there is an invisible light which we do not see but which we feel as heat. This kind of light is referred to as "*infra-red*" or *heat* rays.

It is also known that the spectrum contains another kind of invisible rays which lie above the violet. These are called *ultra-violet*. They do not produce any immediate sensation when they fall on either our eyes<sup>4</sup> or our skin, but when we expose the surface of our bodies to them for a sufficient length of time they

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<sup>4</sup>By the use of a special piece of apparatus it is possible to expose our eyes to ultra-violet light unmixed with visible light. When this is done the observer experiences a sensation which is usually described as "dazzle" or "glare." The authors do not know whether or not this sensation contributes to the "glare" of bright sunlight or not.

produce a painful reddening of the skin which we call a sunburn. It will be seen, therefore, that sunburn is not caused by the invisible heat rays but by the invisible ultra-violet rays of sunlight. Our body may protect itself from these sunburn-producing rays by developing a coat of tan.

The ultra-violet part of sunlight cannot pass through ordinary window glass and, therefore, the chicks which were raised exclusively in the greenhouse, as described in these experiments, did not receive ultra-violet light from the sun. These chicks became afflicted with leg weakness.

In this case it is the ultra-violet part of the sunlight which is essential to the proper formation of the bones in young chicks. Ultra-violet light is undoubtedly important in many other ways to the healthy and normal growth and development of chicks. Nor are the chicks peculiar in their dependency on ultra-violet light, for it is known that when babies are not exposed to ultra-violet light from the sun their bones fail to develop normally and they may become afflicted with a disease called rickets. A child so afflicted is generally bowlegged. Most parents believe bowlegs are caused by allowing the child to stand on its feet too early in life.

There is a special kind of glass called "quartz glass" through which ultra-violet light can pass. In these experiments some of the chickens referred to above were exposed to ultra-violet rays which were produced by a mercury vapor arc which was enclosed in a tube made of quartz glass. The light from a mercury vapor arc is rich in ultra-violet rays. This arc light is similar to the peculiar bluish mercury vapor arc light sometimes seen in the photographer's window, except that the mercury arc in the photographer's window is enclosed in ordinary glass so that the ultra-violet light does not shine out, while the lamp used in these experiments, being enclosed in quartz glass, permits it to pass.

The results of these experiments indicate that the artificial light used gave out more curative ultra-violet rays than is contained in ordinary sunlight, for, as will be seen below, the chicks receiving only a few minutes exposure each day to the rays of the mercury vapor arc showed a more rapid formation of the bone than did the chicks which were exposed many hours each day to the rays of the direct sunlight out of doors.

It is the purpose of this bulletin to show that it is possible to supply by artificial light sources the necessary ultra-violet rays. This may have a very great commercial value for it will allow the poultrymen to raise their chicks indoors at seasons of the year when a proper exposure to the sunlight is impossible.<sup>5</sup>

From other experiments described below it was found that when cod liver oil is added to the diet of chickens which do not receive ultra-violet light, leg weakness is prevented. In these experiments the growth of the chicks receiving cod liver oil was slow. They were not nearly as large as either the chicks receiving direct sunlight or the chicks receiving artificial ultra-violet light.

### THE EXPERIMENTS IN DETAIL

Chickens of three common varieties were chosen as the material for the experiments. Rhode Island Reds (R) and Barred Plymouth Rocks (Rc) were taken as types of the heavier breeds, and White Leghorns (L) as a type of lighter breed.

The chicks were hatched on June 20th. After the first day they were transferred to a greenhouse, allowed to dry for ten days, and on the eleventh day after hatching were separated into pens of twenty-five chicks each. The pens were formed by partitioning off sections of the seed beds of the greenhouse with chicken wire. The greenhouse was provided with the usual roof ventilation so that all of the chicks had an abundance of fresh air. The glass of the greenhouse was partially covered by a coat of whitewash.

The pens were three feet above the floor of the greenhouse and each had three by four feet of floor space. In order to insure that all of the chicks were under the same conditions alternate pens were used for control and treated groups. To prevent crowding more pens were built when the chicks were five weeks old and the groups were subdivided so that each three by four foot pen contained only twelve chicks. All the pens were kept in as sanitary a condition as possible and each was provided with a dust bath.

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<sup>5</sup>The lamp used in this experiment was made by the Cooper-Hewitt Co., Hoboken, N. J. and is sold by them commercially. For details the reader is referred directly to them.

It will be convenient to refer to the pens by numbers:

Pen No. 1, contained sixteen R, five Rc and four L. These chicks were fed in the greenhouse but were permitted to run in a yard open to the sunlight with plenty of green food. A diet of chick grain, dry mash, sour milk, water and rock grit was fed in the greenhouse.

Pen No. 2 contained sixteen R, five Rc and five L. These chicks had no outdoor yard, receiving only glass-filtered sunlight. They were exposed daily for fifteen minutes to the rays of an ultra-violet arc light suspended three feet over their heads. The diet was the same as in Pen No. 1 with the exception that no green food was provided. Dust baths were furnished both in the pen and in the exposing cage.

Pen No. 3, contained eight R, seven Rc and nine L. The chicks were cared for and handled the same as in Pen No. 2 but they were not treated with ultra-violet light. The diet was the same as in Pen No. 2.

Pen No. 4, contained twelve R, three Rc and nine L. The same diet was given as in Pen No. 2 with the addition of green food. A fifteen minute exposure to ultra-violet light was given daily.

Pen No. 5, contained six R, six Rc, and ten L. These chicks were fed cod liver oil with their mash. With this exception in the diet the pen was similar to pen No. 3.

Pen No. 6, contained ten R, four Rc and nine L. An electric fan was turned on these chicks during exposure in order to blow off any gases which might be formed by the lamp. With this exception the pen was similar to No. 2.

Pen No. 7, contained eight R, four Rc and eight L. The same care and diet was given as in Pen No. 3.

Pen No. 8, contained nine R, six Rc and nine L, under the same care and with the same diet as Pen No. 2.

Pen No. 9, contained eleven R, four Rc and nine L. With the exception of being allowed green food, this pen was kept with the same care and under the same diet as Pen No. 3.

In order to make it more convenient to compare the various pens, the following outline is given:

CONTROL		TREATED	
No. 3.	Glass-filtered sunlight Regular diet* Dust bath	No. 1.	Light from sun Regular diet Green food** Dust bath
No. 7.	Same as No. 3	No. 2.	Glass-filtered sunlight Fifteen minutes of ultra-violet daily Regular diet* Exercise in pen only Dust bath
No. 9.	Same as No. 3 plus green food**	No. 4.	Same as No. 2 plus green food**
		No. 5.	Glass-filtered sunlight Regular diet* plus cod liver oil
		No. 6.	Same as No. 2 with air blown from around chicks during exposure to ultra-violet
		No. 8.	Same as No. 2

\*Regular Diet: Chick grain, dry mash, sour milk, rock grit, and water.

\*\*Green Food: Chopped alfalfa and grass.

### EXPERIMENTAL RESULTS

We will present the results of the experiments by: (1) a description of the general appearance of the treated and control chicks, illustrated by figures number 16 and 17; (2) by growth rate (weight) tables of the individual chicks in each pen with a summary table and curves showing the comparison between all treated and control chicks; (3) by mortality tables; and (4) by x-ray photographs (Figures 19-26) showing the degree of bone formation in treated and control chicks.

#### GENERAL APPEARANCE OF TREATED AND CONTROL CHICKS

The exposures to the ultra-violet light began ten days after hatching.

Up until the time the chicks were three weeks old, no difference was observed in the pens of treated and control chicks.





FIG. 17.  
Explanation to figure given on pages 149 and 150.

At the end of the fourth week all of the treated chicks, (a) those exposed to artificial ultra-violet light, (pens 2, 4, 6, 8), (b) those permitted to run out of doors (pen 1) and (c) those receiving cod liver oil (pen 5) appeared to be more vigorous than the control chicks (pens 3, 7, 9) in scratching after food and in their movement about the pens. With the exception of Pen No. 5 they also showed a greater appetite. All of these differences were more marked by the end of the fifth week. The chicks with leg weakness remained in a squatting position most of the time, using the wings for support while moving about after food. The legs appeared to be too weak for scratching.

By this time (end of the fifth week) the weak-legged condition was fully developed, the nails were long and curled, the toes crooked, the bills soft, and the plumage ruffled. The chicks were unable to stand squarely on their feet and were obliged to assume the characteristic posture peculiar to this disease, toes crossed, head low, and so on, in order to maintain their equilibrium.

Figure 16 (the x-ray photographs of these chicks are shown in figures 19 and 20) clearly shows a very conspicuous difference in the size and vigor of the chicks. The smaller chick is a control from Pen 7 and the larger is a treated chick from Pen 6. These birds were five weeks old and typical of the control and treated groups.

The characteristic posture of the unexposed chicks is demonstrated very clearly by the specimen in Figure 17A. The ruffled plumage is shown here better than in the photograph of the smaller chick in Figure 16, but the legs and toes of the former are straighter than those of the latter.

All of these conditions were much more marked at the end of ten weeks. This will be seen from the comparison of the x-ray photographs, Figures 21, 22, 23, and 24. The mortality tables below, show that many of the control chicks died before reaching this age.

It is interesting to compare the typical chick treated with ultra-violet light (Figure 17C, x-ray plate Figure 23), with a chick from Pen No. 1 which was allowed to run in a yard out of doors (Figure 17D, x-ray photograph Figure 24). It is evident that the treated chick is larger and appears more vigorous than the chick exposed to full sunlight. This fact is shown even

more clearly in the x-ray pictures. The x-ray pictures show that the leg bones of chickens treated by fifteen minutes exposure daily to ultra-violet light (Figure 23) are more mature than the leg bones of the chickens shown in Figure 24 which were permitted to run out of doors in the sunlight. The maturity of the bones is shown by their greater opacity. The epiphyseal tissue is completely ossified.

The chick in Figure 17B is particularly interesting. This chick (from Pen No. 3) did not receive any exposure to the ultra-violet light during the first seven weeks of the experiment. At the end of this time the weak-legged condition was fully developed, the chick being completely down on its haunches and unable to stand. It was then given twenty minute exposure to the mercury vapor arc in quartz every day for three weeks, when the treatment was discontinued. The figure shows this chicken some time after the end of the treatment and it is very apparent that it is well on the road to recovery. At the time this is written (twenty weeks) the chicken is vigorous and although fully recovered from the leg weakness, is dwarfed. The x-ray photograph (Figure 21) shows this chick at the age of five weeks. Figure 25 shows the same chick at the age of ten weeks, i.e., after three weeks of treatment.

The chickens fed on cod liver oil (Pen No. 5) did not show the characteristics of leg weakness at the age of ten weeks, as is shown by x-ray photograph (Figure 26), but were much smaller in size than the exposed chicks and those permitted to run out of doors. The addition of green food (chopped alfalfa and grass) to the regular diet (in pens 4 and 6) did not observably affect the time of onset of the disease.

Since ultra-violet light changes the oxygen of the air into the chemically active condition which results in the production of ozone and the oxides of various gases in the air, it was thought that these chemical substances might be responsible for the curative effects of the rays. In order to test this theory, an electric fan was allowed to blow on the chicks in Pen No. 6 during the exposure so that these chemical substances were blown away as fast as they were formed. This did not result in any noticeable difference in the outcome of the experiment. It was concluded, therefore, that these chemical substances play no appreciable part in the curative action of the light.

## EXPLANATION OF TABLES

The following tables, 1-12, pages 152 to 162 give the growth rate (weight) of the individual chicks in each pen with a summary table and curves (Figure 18) showing a comparison between all treated and control chicks.

In all of the tables the letters in the first column indicate the breed of the chick: R, Rhode Island Reds; Rc, Barred Plymouth Rocks; L, White Leghorns.

The letters in the second column indicate the sex of the chicken: M, male; F, female.

The figures in the third column indicate the individual number of the chick.

The data concerning weighings may be taken as a measure of the constancy of the growth rate.

Tables 10 and 11 summarize the results shown in tables 1 to 9.

The percentages given, underneath the totals represent the weight at each date expressed as the percentage of the first weighing of all the chicks receiving the specified treatment.

This figure may be taken as a commercial rating of the value of the treatment, as it represents the net increase in merchantable weight of the chickens that have been fed and cared for under each condition.

The results are presented clearly in the curves shown in figure 18. The total weights expressed in per cent of the total weight at the first weighing are indicated in the vertical direction and the age of the chick in days is shown horizontally.

The broken line shows an increase in weight of all the chickens that received ultra-violet, (Pens 1, 2, 4, 6, 8) and the continuous line shows the increase in the weight of the untreated chicks (Pens 3, 7, 9).

It is interesting and perhaps a very significant fact that, though the opportunities were alike for all the pens, none of the treated chicks were killed by rats. As will be seen from the tables, ten of the chicks in the control pens, that is the untreated chicks (Pens 3, 7 and 9) were so killed; and it was also noted that the chicks killed were in each case the particular ones that were least able to defend themselves or to escape.

We wish to call attention to Table No. 5 showing the weights of the chickens fed on cod liver oil in Pen No. 5. The cod liver oil was added to the regular diet and during the first three weeks the chickens would not eat this diet readily and the increase in weight was delayed so that, as is seen from column 3 in the table, these chickens are all under weight, as compared with the chickens in the other pens. These chickens never have attained full size.

TABLE 1.  
PEN NO. 1—OUTDOOR CONTROL  
*Weight record in twentieths of a pound.*

Breed	Sex	Chick No.	AGE IN DAYS							
			33	37	40	43	52	57	61	66
Rc	M	101	11	14	16	18	20	24	29	33
L	M	102	11	13	15	16	18	20	23	23
R	M	103	9	12	14	16	21	22	24	25
R	M	104	10	12	13	14	20	24	27	31
R	M	105	11	15	16	18	*			
R	F	106	9	11	12	14	19	23	26	30
Rc	F	107	11	12	13	15	19	21	22	24
R	F	103	13	15	16	18	23	26	30	32
R	F	109	8	11	13	14	19	21	23	25
R	F	110	10	13	14	15	20	24	26	31
R	F	111	12	13	14	15	17	19	23	29
R	F	112	9	12	15	16	18	20	21	22
R	F	113	8	10	11	13	17	19	20	22
R	M	114	11	12	13	14	19	23	27	30
Rc	M	115	10	12	14	15	17	21	25	31
L	M	116	12	14	16	17	19	23	29	34
R	F	117	10	12	15	16	18	20	23	25
R	F	118	8	9	10	11	16	18	19	21
R	F	119	8	10	11	13	17	19	20	23
Rc	F	120	8	9	10	12	13	15	16	17
Rc	M	121	5	6	7	8	11	13	15	17
L	M	122	12	14	15	17	18	24	31	39
R	F	123	13	14	15	16	20	23	27	30
L	M	124	10	12	13	15	16	18	21	26
R	F	125	11	13	14	15	17	19	20	23
Total Weights			250	300	335	371	432	499	567	649

\*No. 105 died (intestinal) 53d day.

TABLE 2.

PEN NO. 2—WEIGHT CHART. TREATED

*Weight record in twentieths of a pound.*

Breed	Sex	Chick No.	AGE IN DAYS						
			32	39	44	50	56	61	66
R	M	200	16	20	23	27	29	36	40
L	M	201	11	14	16	18	20	23	27
Rc	M	202	7	11	12	13	16	18	20
R	F	203	11	13	17	20	21	23	28
R	M	204	10	12	14	16	20	22	25
R	M	205	10	13	15	17	18	19	21
R	F	206	13	16	17	18	20	23	26
R	M	207	11	15	17	20	23	24	23
R	M	208	13	16	17	18	21	26	30
Rc	F	209	10	12	15	17	19	22	25
R	M	210	10	14	14	15	17	18	20
R	M	211	14	15	17	20	22	25	29
R	M	212	14	16	20	23	25	27	30
R	M	213	12	16	18	20	21	25	30
R	F	214	11	13	14	15	18	21	24
Rc	M	215	12	16	19	22	25	29	32
R	M	216	11	14	17	19	20	21	23
L	M	217	13	16	18	21	24	29	33
L	M	218	10	14	15	16	21	23	25
Rc	M	219	13	17	19	20	27	30	34
R	M	220	11	15	16	17	18	23	28
R	M	221	10	13	17	18	19	22	27
L	F	222	11	15	16	18	19	22	25
R	M	223	10	13	14	15	16	19	22
L	F	224	11	12	13	16	20	22	24
Rc	M	225	10	13	16	19	22	26	30
Total Weights			295	374	426	478	541	618	706

TABLE 3.

## PEN NO. 3—WEIGHT CHART. INDOOR CONTROL

*Weight record in twentieths of a pound.*

Breed	Sex	Chick No.	AGE IN DAYS							
			33	37	40	43	52	57	61	66
L		300	7	8	*					
L	M	301	11	14	16	17	21	24	27	23
L	F	302	10	11	13	14	15	16	18	19
R	M	303	10	12	13	14	13	19	21	24
Rc	M	304	11	13	13	13	17	19	22	29
Rc	F	305	10	12	13	14	16	16	16	16
Rc	F	306	8	9	11	12	16	17	20	22
L	M	307	8	11	13	16	25	*		
Rc	F	308	10	12	13	14	20	23	25	26
L	F	309	7	9	10	11	15	16	18	20
R	F	310	9	10	11	12	16	19	21	22
Rc	M	311	13	15	16	17	21	25	29	31
R	M	313	11	13	14	15	*			
R	M	314	9	10	10	11	15	16	19	21
R	M	315	11	15	18	20	27	31	37	33
L	M	316	7	8	9	10	15	17	19	20
L	F	317	10	12	13	14	17	17	19	21
Rc	M	319	11	14	15	16	21	22	24	26
Rc	F	321	9	12	13	13	18	20	22	24
R	M	323	12	15	16	17	21	22	24	25
R	F	324	11	15	16	16	20	23	29	23
R	F	325	12	14	14	15	20	24	28	23
Total Weights			217	264	280	301	374	363	438	474

\*No. 300 died 29th day, No. 307 died 58th day, No. 313 died 52d day. These chicks developed weak legs before death.

Withdrawn from experiment

L	M	312	9	14	15	16	20	24	*	
L	F	318	7	9	10	10	11	13	*	

\*No. 312 killed by rat 61st day, No. 318 killed by rat 58th day.

TABLE 4.

PEN No. 4—WEIGHT CHART. TREATED

*Weight record in twentieths of a pound.*

Breed	Sex	Chick No.	AGE IN DAYS						
			32	39	44	50	56	61	66
R	M	400	12	17	18	20	23	29	36
R	M	402	9	12	15	18	20	24	27
R	M	403	8	11	12	15	20	23	27
L	M	404	9	12	14	15	17	20	25
L	F	405	12	14	17	21	22	25	29
L	M	406	13	17	19	22	26	30	34
L	M	407	11	16	18	20	23	27	33
R	M	408	10	12	14	17	19	22	26
R	F	410	9	12	16	19	23	26	29
R	M	411	10	13	17	21	25	27	30
R	F	412	13	16	19	23	26	28	31
R	F	413	12	14	19	24	26	29	32
L	F	414	10	13	15	18	21	24	27
Re	F	415	10	13	15	18	21	25	30
L	F	416	11	15	17	20	25	28	31
Re	M	417	10	13	15	17	20	23	26
R	M	418	10	14	15	17	20	23	27
L	M	419	12	15	17	20	22	27	32
R	M	420	13	17	20	23	27	32	37
L	M	421	12	16	20	24	27	31	36
Re	F	422	12	15	18	20	25	28	32
R	F	423	11	14	16	17	20	23	27
R	F	424	10	13	15	18	21	24	29
L	F	425	9	12	15	17	20	23	27
Total Weights			258	336	396	464	539	621	710

TABLE 5.

PEN NO. 5—WEIGHT CHART. CONTROL—COD LIVER OIL

*Weight record in twentieths of a pound.*

Breed	Sex	Chick No.	AGE IN DAYS							
			33	37	40	43	52	57	61	66
L	F	500	8	10	11	12	15	18	20	21
L	M	501	9	11	15	16	17	13	18	20
L	F	502	9	11	15	16	13	20	25	32
L	M	503	11	13	15	16	17	20	21	23
Rc	F	504	6	8	9	10	13	15	16	19
R	F	505	6	8	10	11	12	14	15	17
R	F	506	5	7	9	10	11	13	14	16
Rc	F	507	7	9	11	12	14	16	17	19
Rc	F	508	6	8	9	10	14	16	17	19
Rc	F	509	6	7	7	8	9	9	10	11
L	F	510	8	10	12	12	15	17	18	21
L	F	511	6	9	11	12	16	19	20	21
L	F	512	10	13	15	16	20	22	23	26
L	F	513	10	13	16	17	20	23	24	28
Rc	F	514	6	8	10	11	15	16	17	20
R	M	515	7	10	12	13	17	20	21	23
L	F	516	9	11	14	16	13	20	22	26
R	F	517	5	7	9	9	11	13	14	17
L	F	519	10	12	16	18	21	24	25	26
L	M	520	8	10	13	14	18	21	23	25
L	M	521	10	13	15	16	21	25	26	29
Total Weights			169	217	266	283	349	399	427	484

TABLE 6.

PEN NO. 6—WEIGHT CHART. TREATED

*Weight record in twentieths of a pound.*

Breed	Sex	Chick No.	AGE IN DAYS						
			32	39	44	50	56	61	66
R	F	600	12	16	17	19	21	25	30
L	F	601	13	15	17	20	24	27	31
L	M	602	12	15	16	18	20	24	29
Rc	M	604	10	14	18	20	22	27	33
Rc	M	605	11	14	16	18	22	24	29
L	F	606	10	12	15	17	20	23	26
R	M	607	11	15	17	19	25	28	32
Rc	F	608	12	14	16	18	20	24	29
L	F	609	10	15	18	19	23	27	32
R	F	610	11	14	15	16	17	20	24
Rc	M	611	12	16	18	20	25	30	35
L	M	612	12	14	17	20	24	27	32
R	F	613	8	10	14	16	17	18	19
L	F	615	9	12	14	16	18	21	24
R	M	616	14	18	19	23	25	29	34
R	M	617	11	15	18	21	25	30	35
L	M	618	10	12	15	18	23	26	30
R	F	619	8	12	13	14	15	17	20
L	F	620	10	14	16	19	20	23	27
L	F	621	9	11	12	13	14	17	18
R	M	622	11	14	17	20	25	29	34
R	M	624	12	16	19	24	29	34	40
R	F	625	11	13	15	16	18	20	23
Total Weights			249	321	372	434	492	570	666

TABLE 7.

## PEN NO. 7—WEIGHT CHART. INDOOR CONTROLS

*Weight record in twentieths of a pound.*

Breed	Sex	Chick No.	AGE IN DAYS							
			33	37	40	43	52	57	61	66
R	F	701	11	13	14	14	17	18	18	19
		702	10	12	11	10	*			
L	F	703	11	12	13	13	16	17	19	27
Re	M	704	10	10	10	12	19	20	21	25
Re	M	705	7	8	7	7	8	8	9	11
L	F	708	11	12	12	12	15	18	15	16
L		709	8	9	9	*				
R		710	7	8	9	*				
R		711	8	8	8	9	*			
R		712	6	6	6					
L	M	713	11	12	13	14	20	21	23	27
L		716	11	12	11	13	*			
L		717	8	8	8	9	*			
Re		718	6	7	8	8	*			
L		721	7	8	8	8	*			
R	M	723	10	11	11	12	16	16	17	20
Total Weights			142	156	152	141	111	118	122	145

\*No. 702 died 51st day, No. 709 died 44th day, No. 710 died 44th day, No. 711 died 51st day, No. 712 died 39th day, No. 716 died 51st day, No. 717 died 45th day, No. 718 died 39th day, No. 721 died 45th day. All these chicks developed weak legs before death.

## Withdrawn from experiment

R	700	7	7	7	8	*			
R	706	7	7	7	9	*			
Re	707	8	8	8	8	*			
R	715	8	9	9	9	8	*		
L	722	8	8	7	6	6	*		

\*No. 700 killed by rat 51st day, No. 706 killed by rat 51st day, No. 707 killed by rat 52nd day, No. 715 killed by rat 60th day, No. 722 killed by rat 60th day.

TABLE 8.

## PEN No. 8—WEIGHT CHART. TREATED

*Weight record in twentieths of a pound.*

Breed	Sex	Chick No.	AGE IN DAYS						
			32	39	44	50	56	61	66
L	F	800	14	16	18	19	22	25	29
R	M	801	12	14	17	20	21	22	23
R	M	802	13	17	20	24	25	26	27
L	F	803	13	18	21	25	27	28	30
L	M	804	14	16	22	24	26	29	32
R	M	805	8	13	17	19	20	22	25
Rc	M	808	15	17	23	25	27	30	33
L	M	809	9	12	15	18	21	22	24
Rc	M	810	11	13	17	21	23	28	32
L	F	811	10	12	17	19	21	24	27
R	M	812	12	15	20	22	25	27	30
R	M	813	13	16	20	24	28	31	36
Rc	F	814	9	12	15	17	18	19	20
Rc	F	815	12	15	18	21	24	26	28
L	M	816	12	16	22	25	27	33	37
L	M	817	12	16	19	20	22	25	30
R	M	818	12	14	*				
R	F	820	15	16	19	20	22	26	30
L	F	822	6	9	11	12	14	15	17
R	F	823	14	17	18	23	25	26	27
L	M	824	13	17	21	22	23	25	28
Rc	F	825	8	11	13	14	15	16	17
R	M	826	12	15	20	25	26	30	36
Total Weights			269	337	403	459	502	555	618

\*No. 818 died (intestinal) 43rd day.

Removed after injury

Rc	M	806	12	16	21	25	27		
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TABLE 9.

## PEN NO. 9—WEIGHT CHART. INDOOR CONTROLS

*Weight record in twentieths of a pound.*

Breed	Sex	Chick No.	AGE IN DAYS							
			33	37	40	43	52	57	61	68
R	M	900	15	17	13	20	25	27	29	31
L	M	901	11	14	14	15	15	21	24	26
L	M	903	12	16	16	17	20	21	21	21
Rc		905	7	8	9	10	*			
R	M	906	12	14	15	16	20	23	27	31
Rc	M	907	10	11	11	12	15	18	20	21
R	M	903	11	12	13	15	19	22	27	30
R	F	900	12	15	16	17	21	23	26	31
L	F	911	12	14	15	16	18	19	20	21
L	F	912	11	12	12	13	14	15	15	14
L	M	913	13	16	17	19	24	26	29	31
Rc	M	914	8	10	10	10	11	13	14	15
R	F	915	10	11	11	11	13	14	15	15
R	F	916	10	13	13	14	15	17	19	20
R	M	917	9	11	12	14	18	21	25	23
R	F	918	12	15	16	16	19	19	19	19
Rc	F	919	9	10	11	12	17	18	18	19
R		920	8	10	9	9	*			
L		921	10	12	12	12	12	*		
R	F	923	12	15	16	17	19	20	22	22
R		924	8	9	*					
Total Weights			222	265	266	235	318	337	370	395

\*No. 905 killed by rickets 52d day, No. 920 died (weak legs) 46th day, No. 921 died (weak legs) 53d day, No. 924 died (intestinal) 40th day.

## Withdrawn from experiment

L		902	7	8	9	9	10	*		
L		904	10	14	15	15	*			
L		910	7	7	7	8	8	*		

\*No. 902 killed by rat 60th day, No. 904 killed by rat 50th day, No. 910 killed by rat 53d day.

TABLE 10.

## CONTROLS

*Weight record in twentieths of a pound.*

	AGE IN DAYS				
	33	40	51	61	65
Pen No. 3	217	280	374	438	474
Pen No. 7	142	152	111	122	145
Pen No. 9	222	266	318	370	395
Total Weights	581	698	803	930	1014
Per Cent	100	120.13	133.21	160.07	174.50

TABLE 11.

## TREATED

*Weight record in twentieths of a pound.*

	AGE IN DAYS				
	33	39	49	60	65
Pen No. 1	250	300	432	567	649
Pen No. 2	295	374	478	618	706
Pen No. 4	258	336	464	621	720
Pen No. 6	249	321	434	570	666
Pen No. 8	269	337	459	555	618
Total Weights	1321	1668	2267	2931	3359
Per Cent	100	126.2	170.8	221.8	254.2

TABLE 12.  
THE MORTALITY TABLE

Age in days:	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65
Date: July and August	23	24	25	26	27	28	29	30	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Age in weeks:	5						6							7						8								9					
Pen No. 3							1											1															
Pen No. 7							2				2	2						3															
Pen No. 9								*					1						1	1													
Pen No. 5																																	
Pen No. 1																				*													
Pen No. 2																																	
Pen No. 4																																	
Pen No. 6																																	
Pen No. 8									*																								

Numbers of deaths from rickets indicated by figures.  
Each death from intestinal derangement indicated by \*.

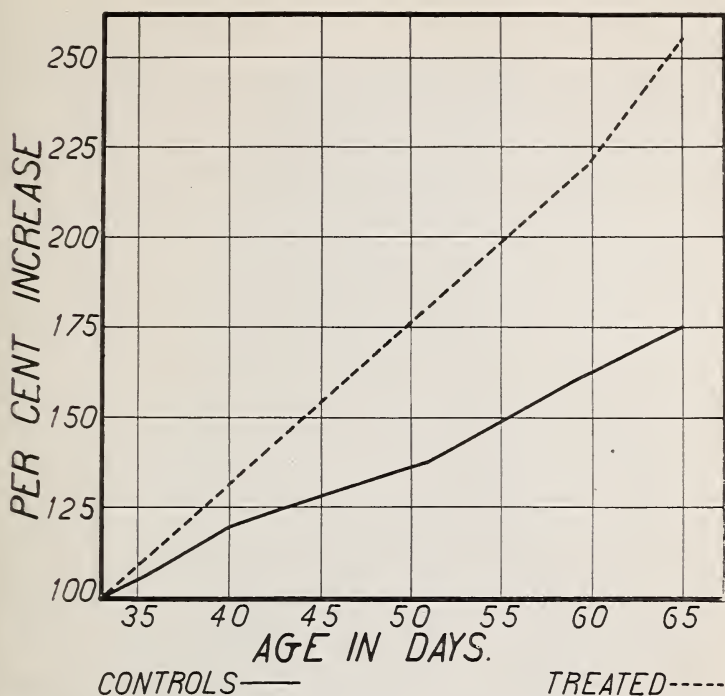


FIG. 18. Comparative rate of gain of treated chicks and controls.

#### DISCUSSION

These experiments which are preliminary in nature, have been released for publication in order that the importance of outdoor sunlight or ultra-violet light in the raising of chicks might again be emphasized; and to bring out the value of this particular kind of light in the normal growth and development of other kinds of farm animals.

The failure in the growth of chicks receiving an insufficient amount of ultra-violet light, as reported in these experiments, has been traced to a failure in the development of bone tissues. It may be said that a like failure in the growth and development of bones has been observed in cattle in certain districts in Africa where there was a lack of the calcium and phosphorous salts in the soil. In this case the disease was cured either by feeding the animals on green bone or by fertilizing the land with calcium and

rock phosphate. These experimental results differ from those from South Africa in that these chicks were provided with plenty of calcium and phosphorus in their food and an analysis of their blood shows no deficiency in the amount of bone-forming salts. For some unknown reason, without the exposure to ultra-violet light these salts, although present in the blood, do not deposit in the bone. In this respect there is a parallelism between plants and animals, for it is a well-known fact that in plants there may be a great abundance of sugar in the sap, but this sugar is not deposited to form woody tissue without exposure to light. We take advantage of this fact when we bleach celery. The celery contains an abundance of sugar and tastes sweet, but the mechanical supporting tissue fails to develop. The celery is therefore tender and succulent. That other physiological processes are influenced by the presence of light is evidenced by the fact that bleached celery does not contain as large an amount of the essential oil to which the flavor of celery seed is due, as does the unbleached celery. Celery growing in the light has a strong, rank taste. There is evidence that further investigation will reveal many other physiological processes which are controlled or are influenced by light.

We have not determined the amount of ultra-violet light which is best for the normal development of chickens nor have we determined what effect an excess of ultra-violet light would have on their growth or development.

While the experiments reported in this bulletin are few in number we have much of confidence in the results, for similar results have recently been obtained in other experimental laboratories. They are introductory experiments which mark the beginning of what we believe will become a very profitable line of investigation.

The true nature of leg weakness in chicks is revealed by the x-ray photographs shown in this bulletin.

The x-ray photographs show a deficiency in the deposit of calcium and phosphorus salts in the bone. Since the deposit of these salts is necessary to bone growth, leg weakness is naturally a disease of growing chickens. A failure in calcium and phosphorus deposit is of course not peculiar to the growing animal, but the results are more conspicuous in a growing chick. It is, however, clear that both light and lime (calcium) are necessary to successful rapid growth of chicks.



FIG. 19. Treated chick at age of five weeks showing typical bone development of chicks from pens No. 2, 4, 6, and 8.





FIG. 20. Control chick at age of five weeks showing typical bone development of chicks from pens No. 3, 7, and 9.





FIG. 21. Chick from control pen at age of ten weeks showing typical bone development which accompanies leg weakness.





FIG. 22. Chick from control pen at age of ten weeks showing typical bone development which accompanies leg weakness.





FIG. 23. Treated chick at age of ten weeks showing contrast of bone development with outdoor control from pen No. 1. FIG. 24. This treated chick shows ossification of epiphyses much in advance of normal chick.





FIG. 24. Outdoor control chick at age of ten weeks showing contrast of bone development with treated chick shown in Fig. 23.





FIG. 25. The same chick as shown in Fig. 21 at the age of ten weeks after having received treatment for only three weeks. A marked improvement in bone development is evident in tibia and at epiphyses.





FIG. 26. Chick from pen No. 5 at age of ten weeks. These chicks fed on cod liver oil show normal bone development.

## LIST OF RECENT BULLETINS

- No. 305. The Relation of Tree Type to Productivity in the Apple.  
No. 306. Studies in Milk Secretion. XVII. Relation between Milk Yields and Butter-Fat Percentages of the 7-day and 365-day Tests of Holstein-Friesian Advanced Registry Cattle.  
No. 307. Sterility Relationships in Maine Apple Varieties.  
No. 308. The Blueberry Maggot in Washington County.  
No. 310. The Cause and Permanence of Size Differences in Apple Trees.  
No. 311. The Effect of Age on the Milk Yields and Butter-Fat Percentages of Guernsey Advanced Registry Cattle.  
No. 312. Potato Spindle-Tuber.  
No. 313. The Summer Food Plants of the Green Apple Aphid.  
No. 314. Studies on Conformation in Relation to Milk Producing Capacity in Cattle. III. Conformation and Milk Yield in the Light of the Personal Equation of the Dairy Cattle Judge.  
No. 315. Abstracts of Papers not Included in Bulletins, Finances, Meteorology, Index.  
No. 316. The Importance and Natural Spread of Potato Degeneration Diseases.  
No. 317. The Buckthorn Aphid.  
No. 318. Interpretation of Dairy Pedigrees.  
No. 319. The Blueberry Leaf-beetle and Some of Its Relatives.  
No. 320. Influence of Ultra-violet Light on Nutrition in Poultry.

The following bulletins are published in limited editions and are mailed regularly to libraries and to other institutions in exchange. They represent types of publications which are not sent to general mailing lists in the State but will be forwarded to any address on request, as long as the supply lasts.

### Bulletin 317.

THE BUCKTHORN APHID. This bulletin contains an account of a small greenish aphid that overwinters on the buckthorn (*Rhamnus*) in the egg stage. The first spring generation develops on the buckthorn leaves, distorting them. Later winged generations disperse to seventy or more different species of plants which the aphids infest during the summer. The bulletin gives the life history of the aphid; a list of all its known food-plants, many of which are of economic importance; a record of the habits of the species which is a pest in vegetable and flower gardens; a report of its role as a carrier of plant disease; and suggestions for control.

### Bulletin 319.

THE BLUEBERRY LEAF-BEETLE AND SOME OF ITS RELATIVES. Bulletin 319 contains an account of fifteen New England leaf-beetles belonging to the genus *Galerucella*. Five of these being previously unnamed, are described as new species. Among this number is a dull yellow or reddish brown beetle which is indicated as the blueberry leaf-beetle as both the adult beetles and their larvae feed upon blueberry leaves. The females deposit eggs from late May to late July so that a succession of the larvae are present for about eight weeks. The bulletin gives a description of the egg, larva and adult insect with drawings and photographs; an account of its distribution, foodplants, hibernation and other habits, natural enemies, and suggestions as to its control. Similar though briefer descriptive accounts are given of the other species and a key makes possible an identification of the different species.



